



Major climate science challenges and opportunities

Jean-François Lamarque

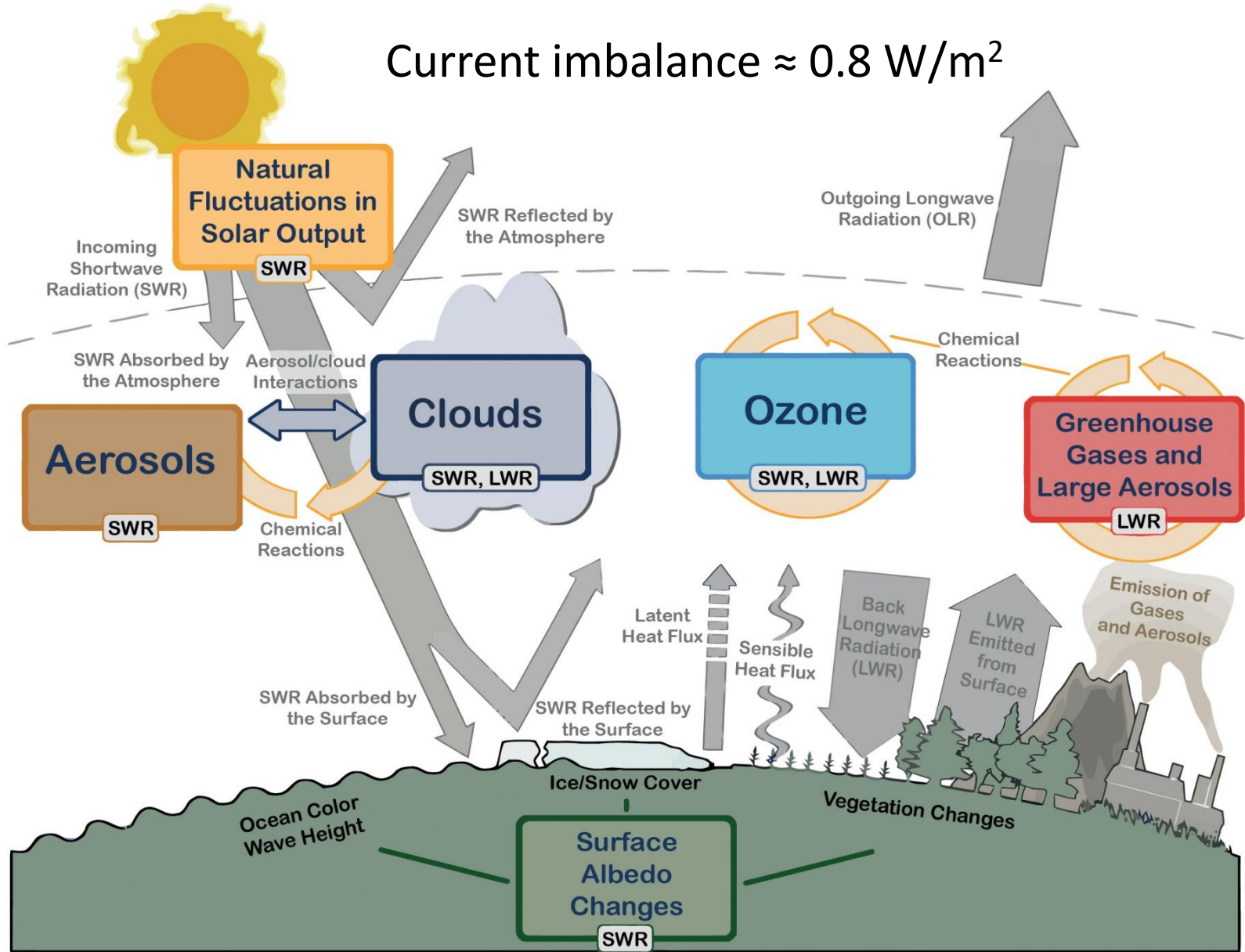
Director of the Climate and Global Dynamics Laboratory

NCAR

Boulder, CO



IPCC AR5
Ch. 1



Precipitation trends

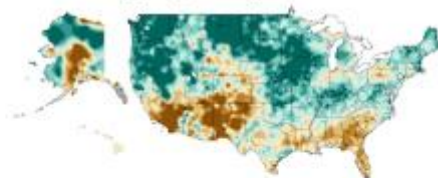
Annual Precipitation



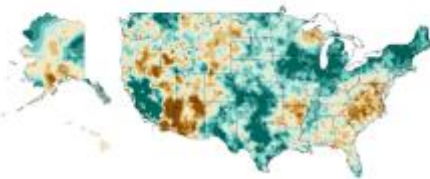
Winter Precipitation



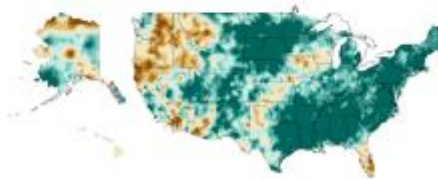
Spring Precipitation



Summer Precipitation



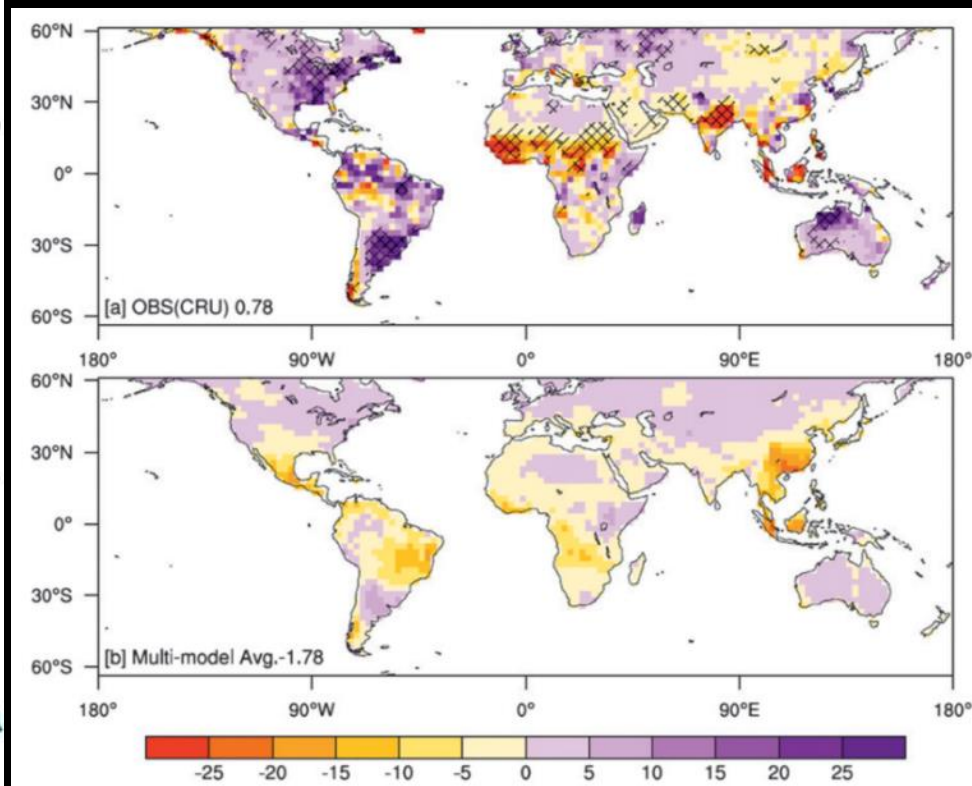
Fall Precipitation



(1986-2015) minus (1901-1960)

Easterling et al, 2017

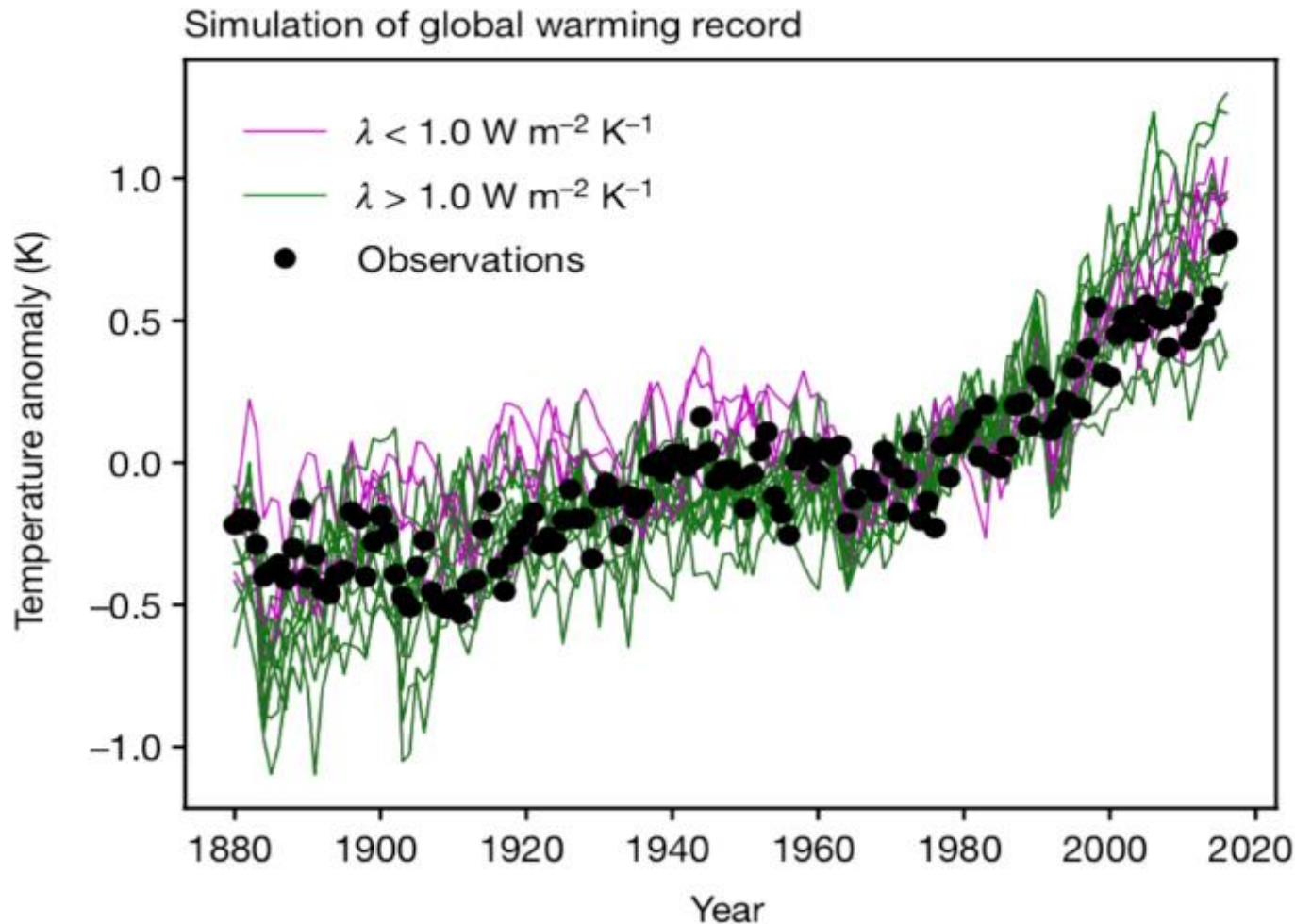
Fourth National Climate Assessment, Volume I



1930-2004 annual mean precip trend
mm/decade

Kumar et al., J. Climate, 2012

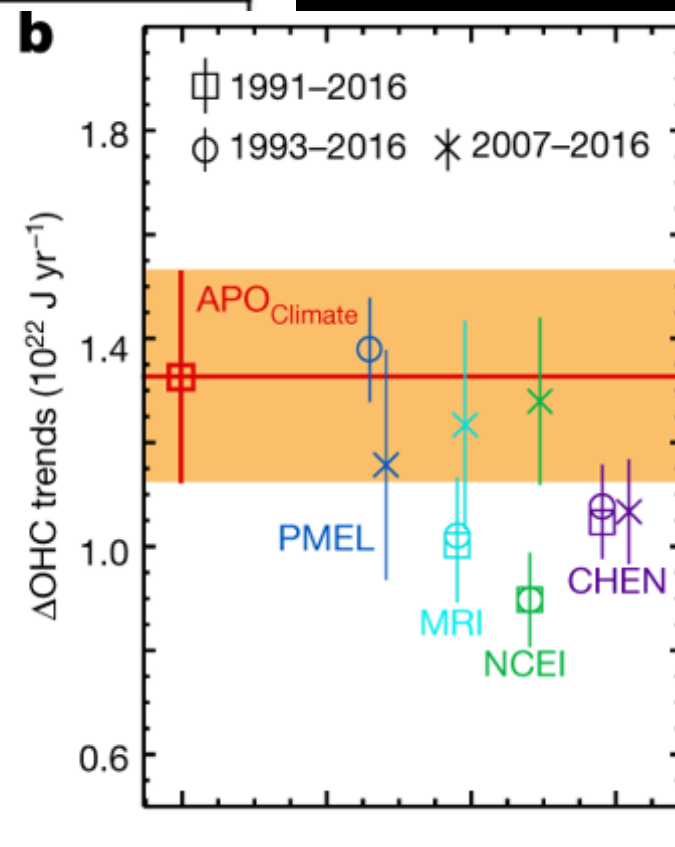
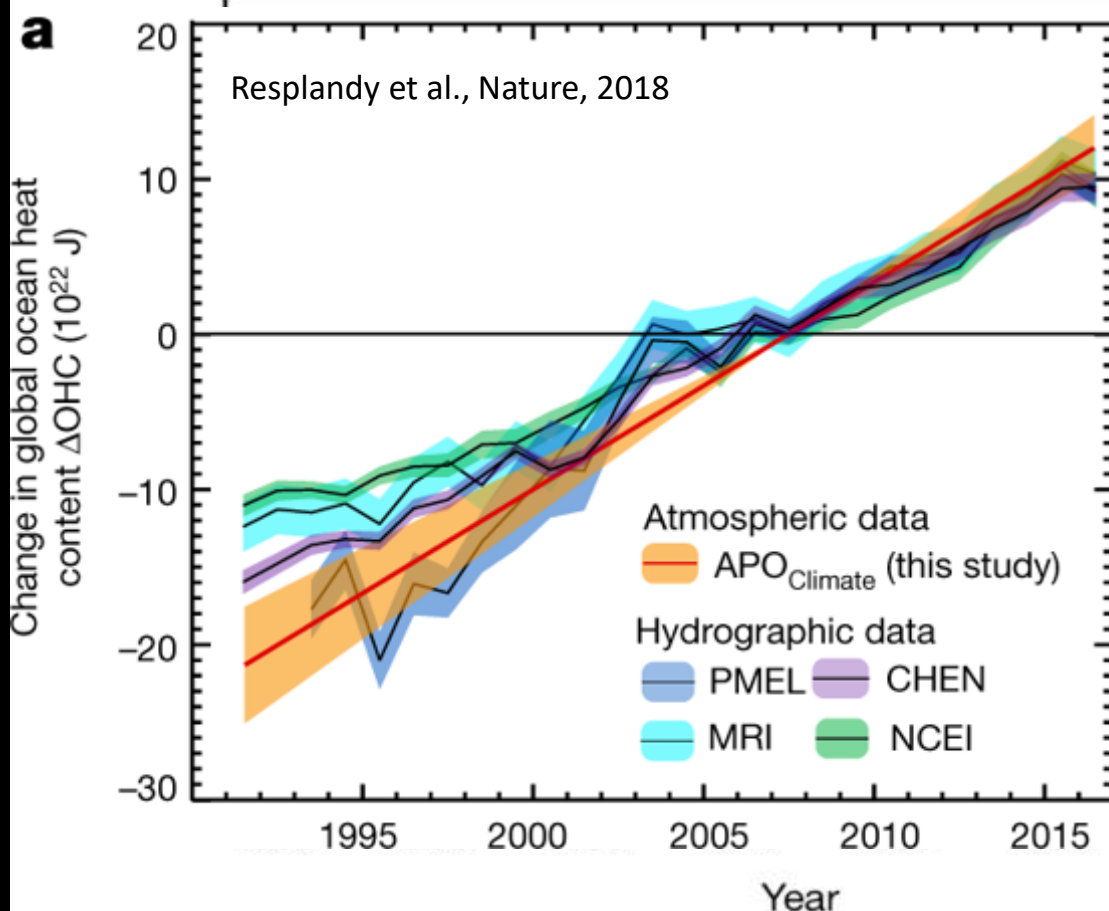
Global- annual-mean surface temperature



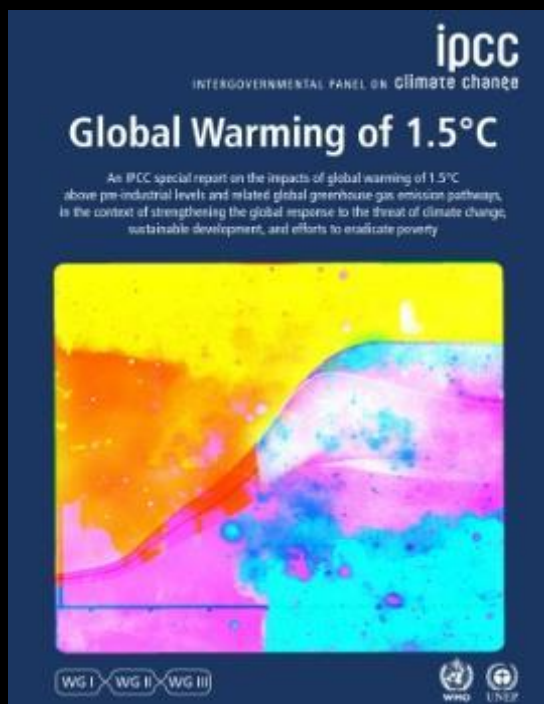
Cox et al., Nature, 2018

Global- annual-mean surface temperature

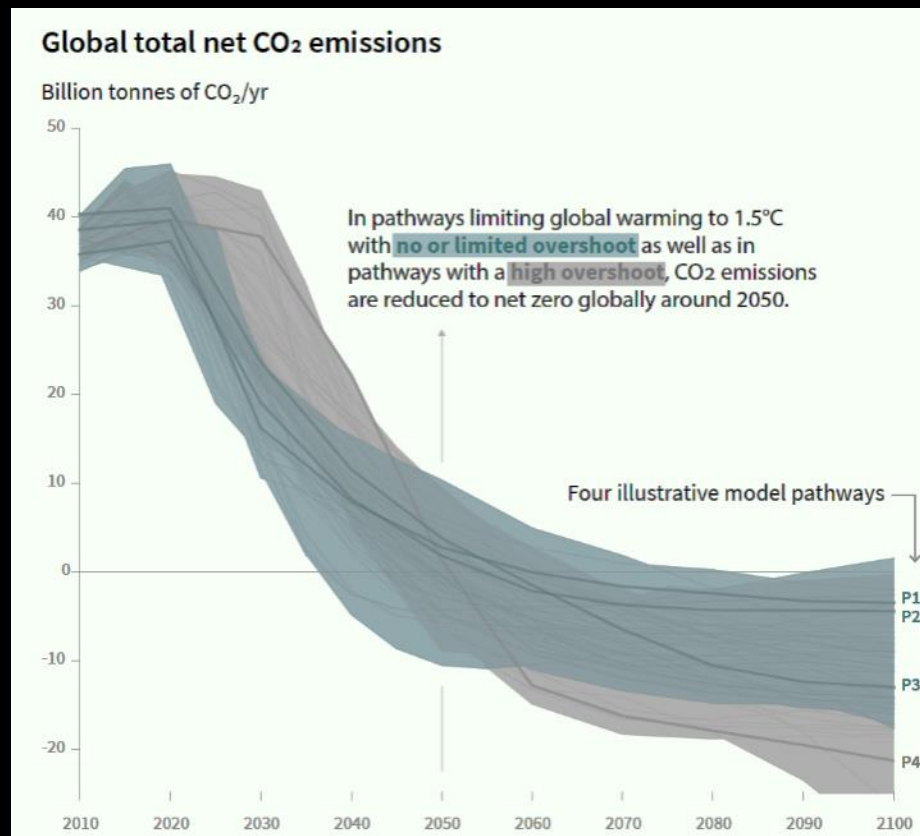
Simulation of global warming record



IPCC SR1.5

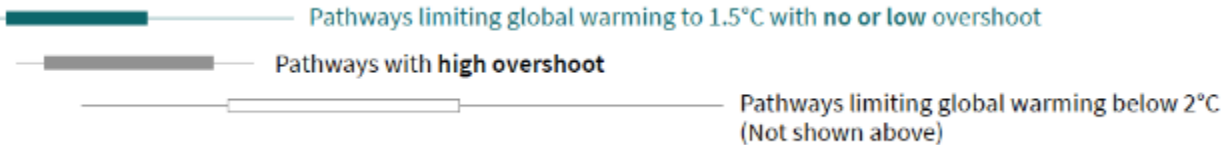


From IPCC SR1.5 SPM

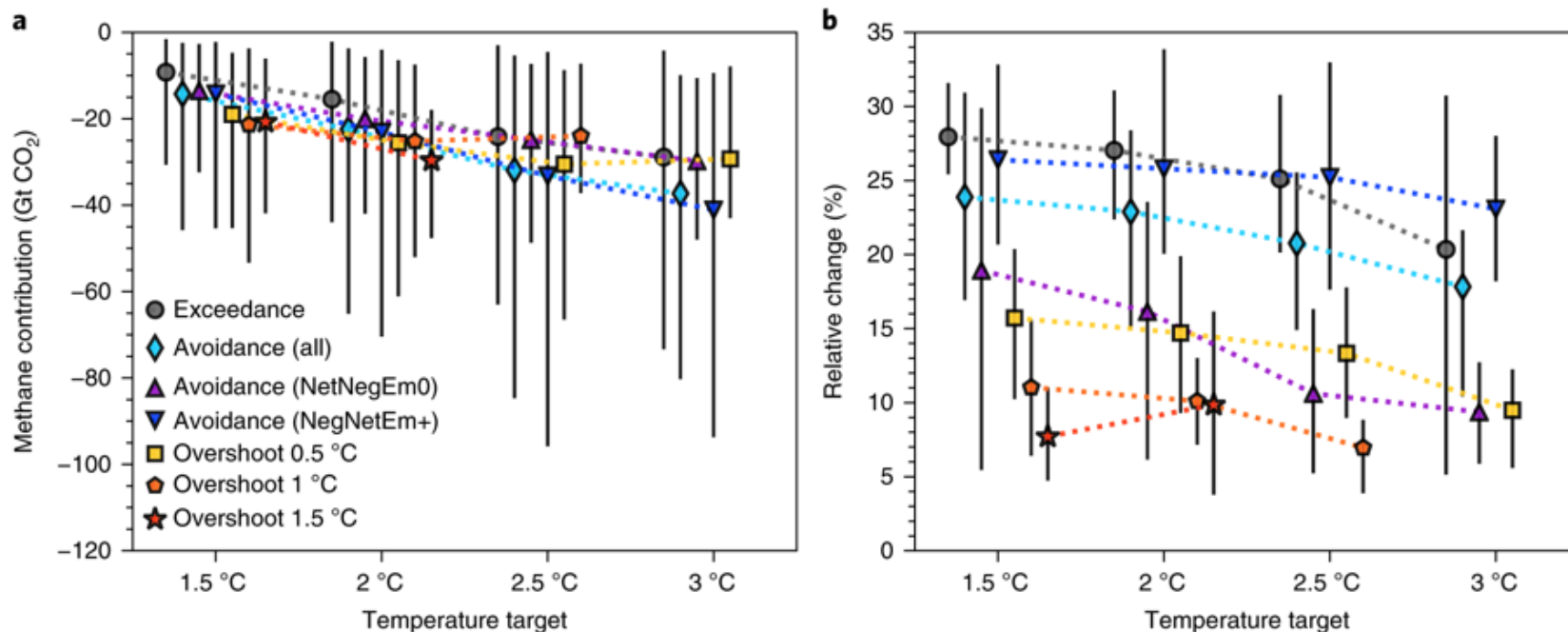


Timing of net zero CO₂

Line widths depict the 5-95th percentile and the 25-75th percentile of scenarios

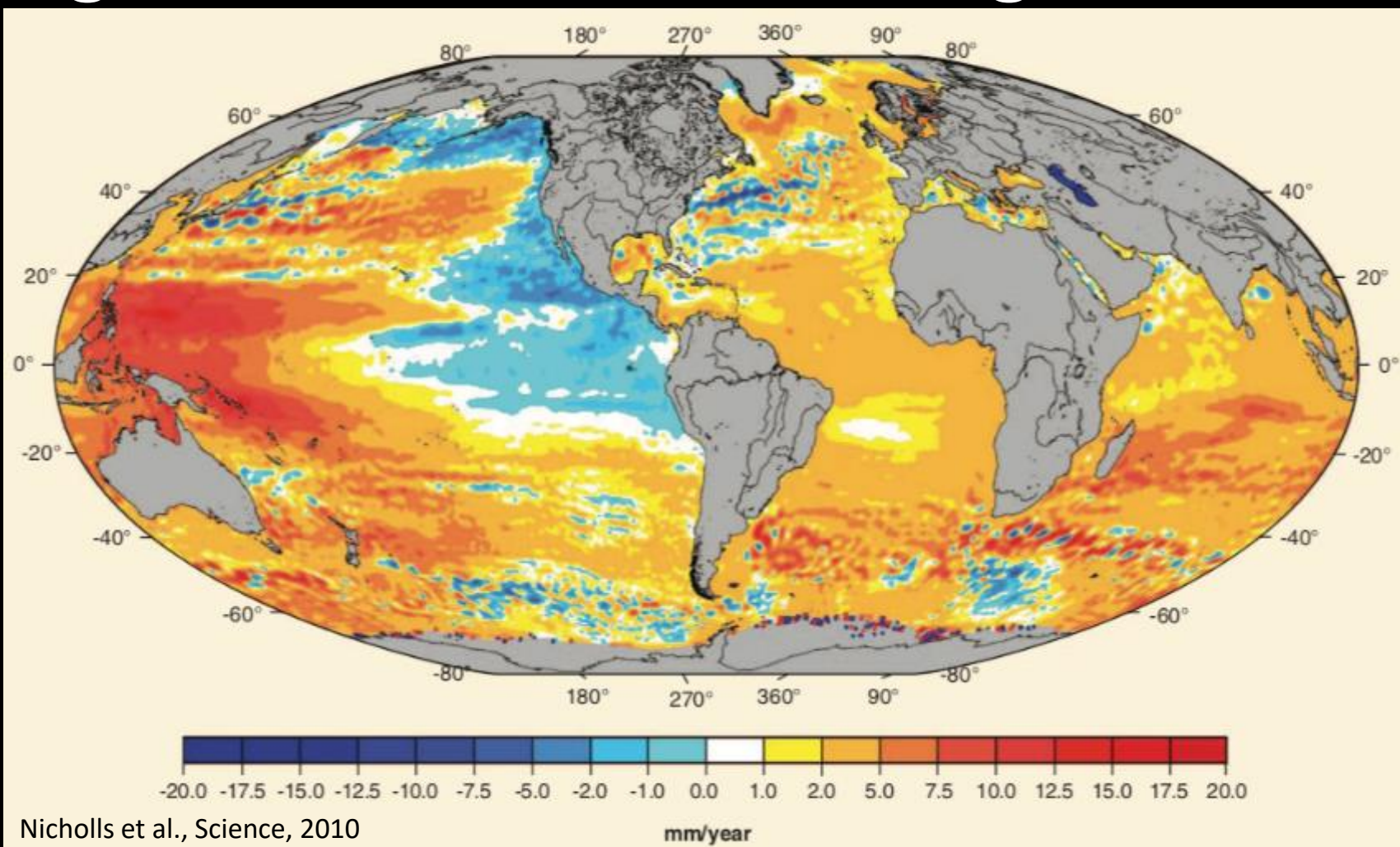


Earth System feedbacks: permafrost CO₂ and CH₄ fluxes



a,b, Absolute (**a**) and relative (**b**) terms with regard to the values shown in Fig. 2a. Uncertainty bars show the full range and symbols show the average, across all permafrost models and scenarios.

Regional sea level rise: is there a signal from aerosol forcing?

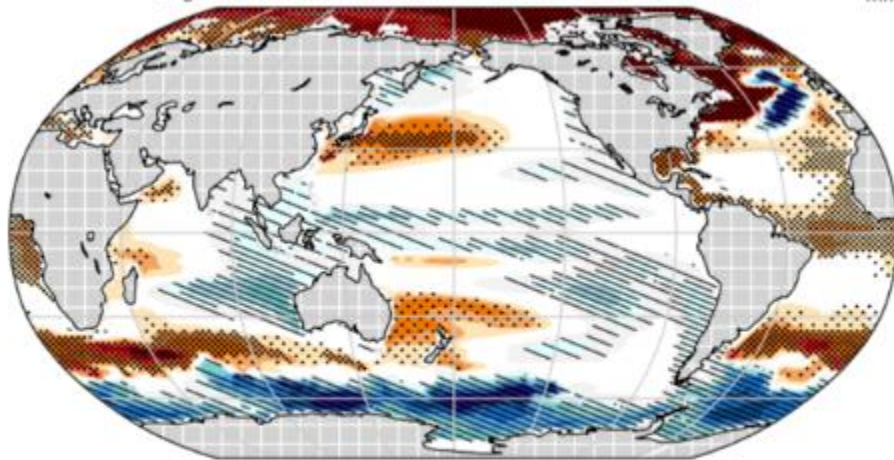


Regional sea level rise: is there a signal from aerosol forcing?

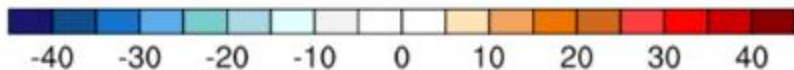


Large Ensemble : Annual Mean Trend : SSH : 1993-2020 : 40mem

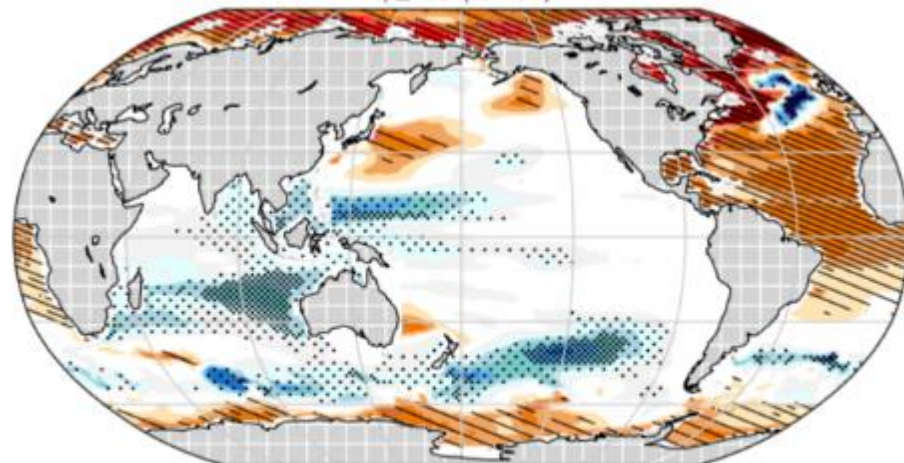
mm



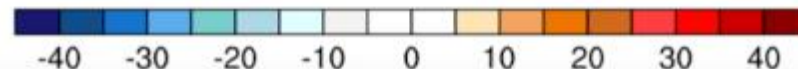
All forcings (1993-2020)



c) Δ xaer (20 mem)



Aerosols only



Seasonal to decadal prediction

- Fundamentally a coupled problem
- Different scales of predictability operate on different modes of coupling
 - Ocean

Decadal Prediction Large Ensemble with CESM1

The CESM Decadal Prediction Large Ensemble:
Forecasting decadal trends in the
North Atlantic and Arctic

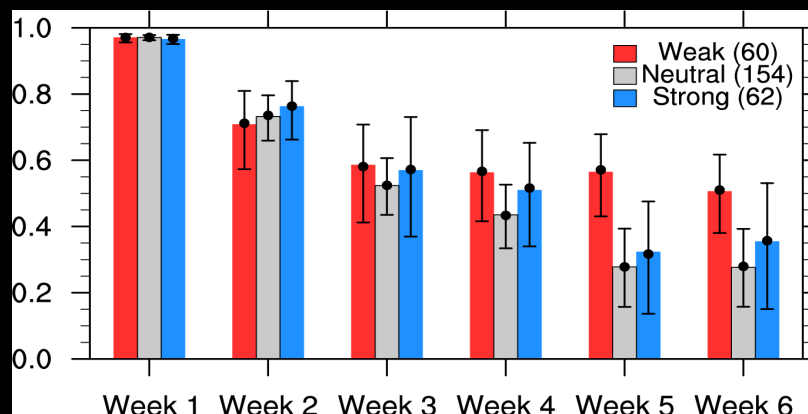
Seasonal to decadal prediction

- Fundamentally a coupled problem
- Different scales of predictability operate on different modes of coupling
 - Ocean
 - Stratosphere

NAO Predictability: Influence of the Stratosphere

- Research with CESM1 S2S hindcasts
- Following extreme stratospheric polar vortex conditions, the **NAO predictive skill up to week 6 is generally higher compared to stratospheric neutral vortex states.**
- The enhanced NAO predictive skill **for weak vortex events is related to stratospheric downward coupling**, while in the case of strong vortex events the skill is partly related to persistence and lower boundary forcing.

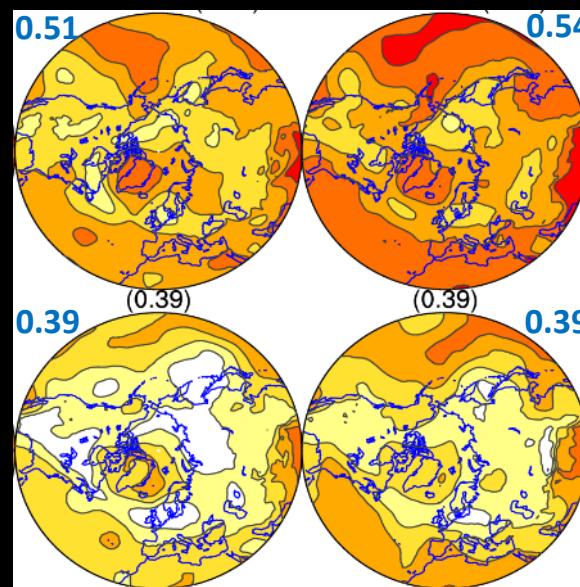
ACC of weekly NAO in dependence of initialized 10hPa polar vortex strength



*Sun et al. (2018)
in preparation*

CESM1

ECMWF



Week 3

Week 4

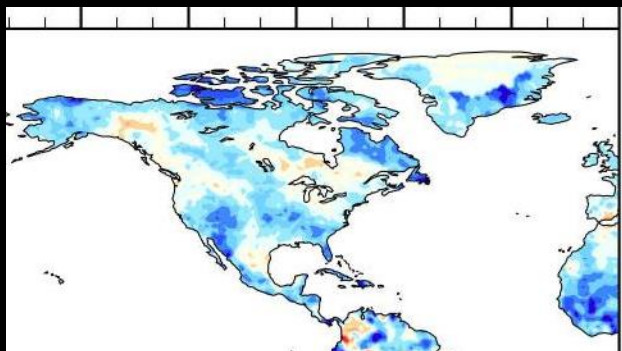
NOAA funded project: J. Richter (NCAR) & J. Perlwitz & L. Sun (NOAA/ESRL/PSD)

Seasonal to decadal prediction

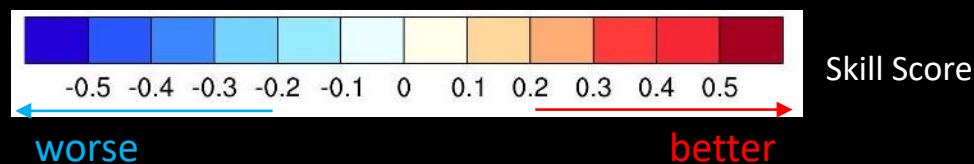
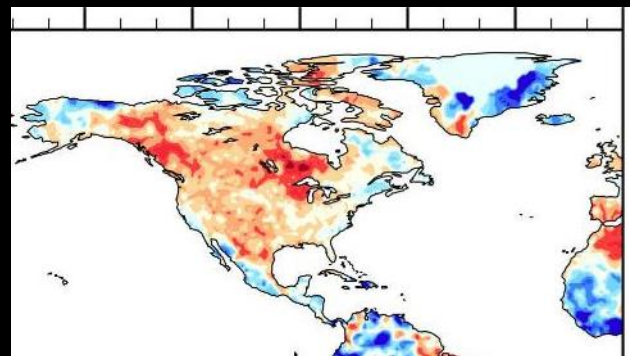
- Fundamentally a coupled problem
- Different scales of predictability operate on different modes of coupling
 - Ocean
 - Stratosphere
 - Land

Surface Air Temperature Predictions over North America with CESM on Monthly Time Scales

Old version (CCSM3)



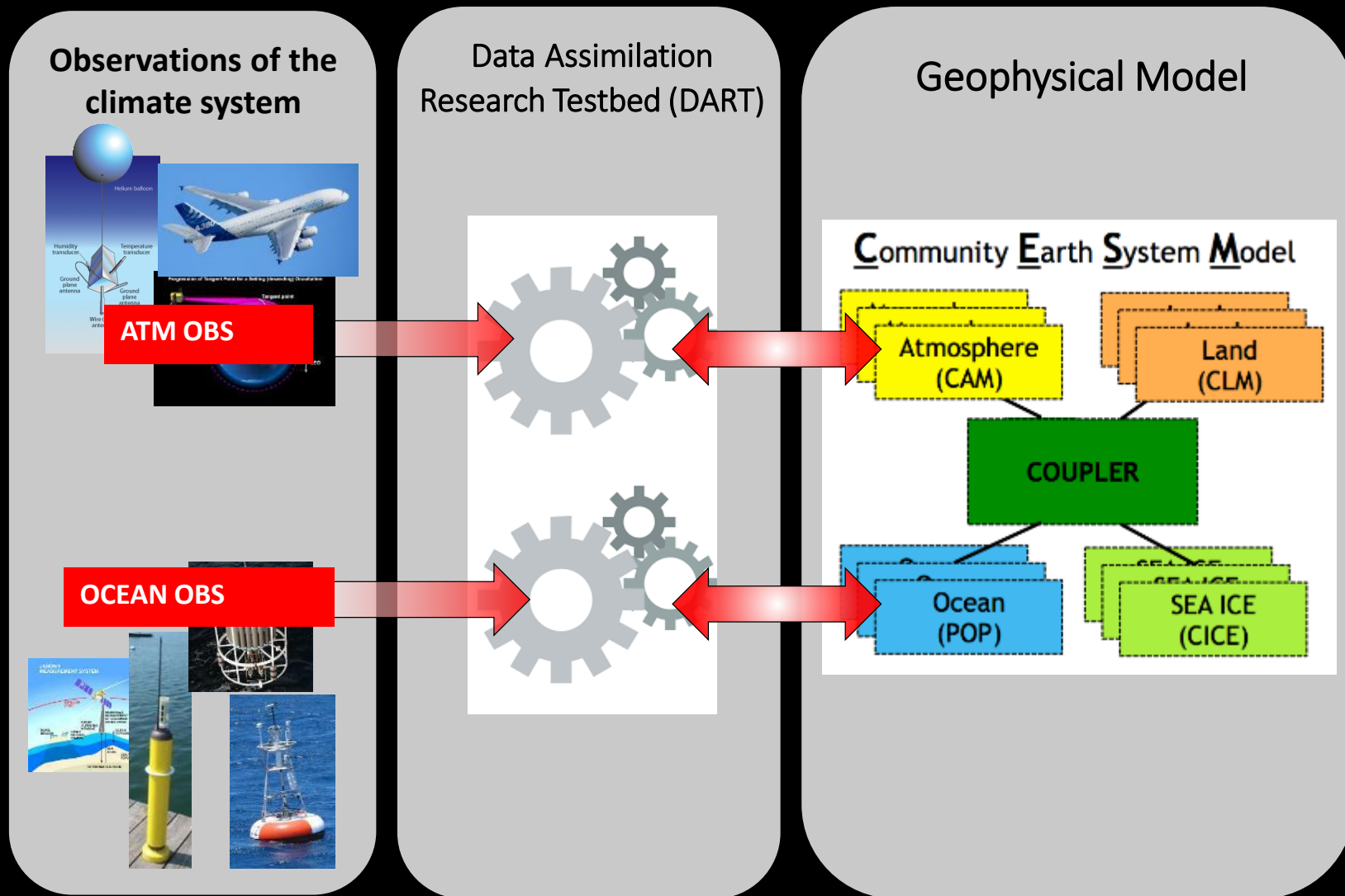
New Version (CESM1)



Better models and better (ocean) initial conditions lead
to better surface temperature predictions over land

01 January starts; verifying January-means for 1982-2010

“WEAKLY” Coupled Data Assimilation: The cutting Edge



“STRONGLY” Coupled Data Assimilation: A research problem

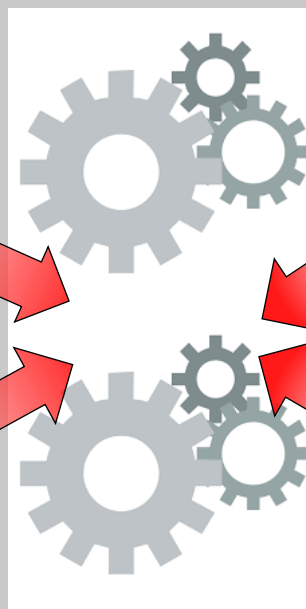
Observations of the climate system



OCEAN OBS

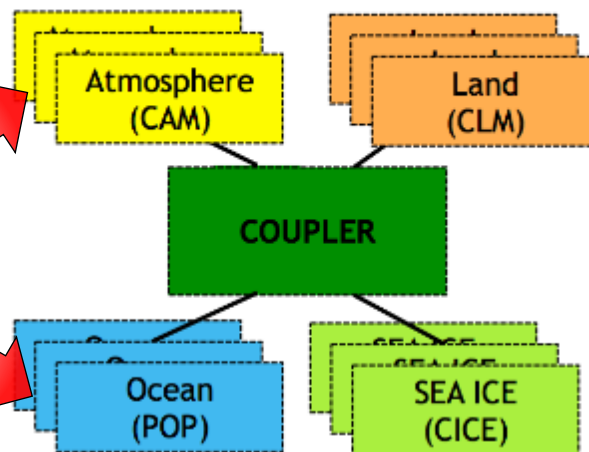


Data Assimilation Research Testbed (DART)



Geophysical Model

Community Earth System Model



March 10 2013-2018



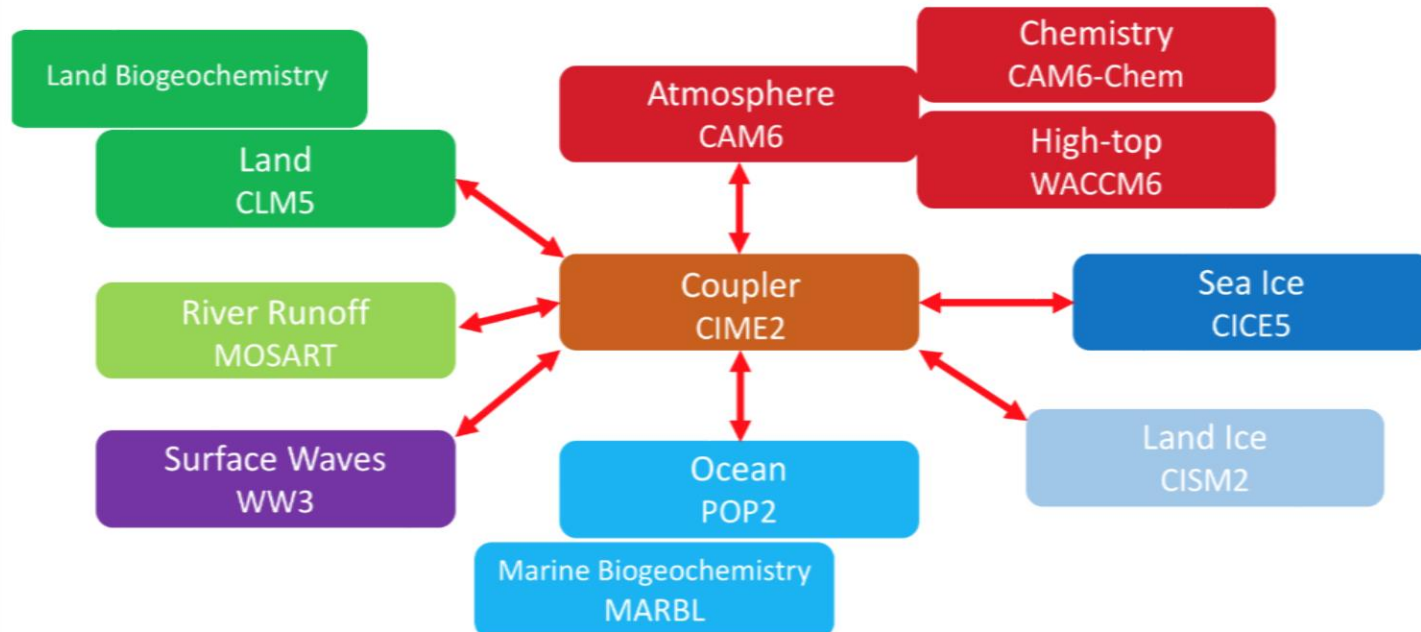
What is climate change? What is variability?

Additional slides



Community Earth System Model (CESM)

CESM 2.0 was released to the community on 8 June 2018!



CESM Project

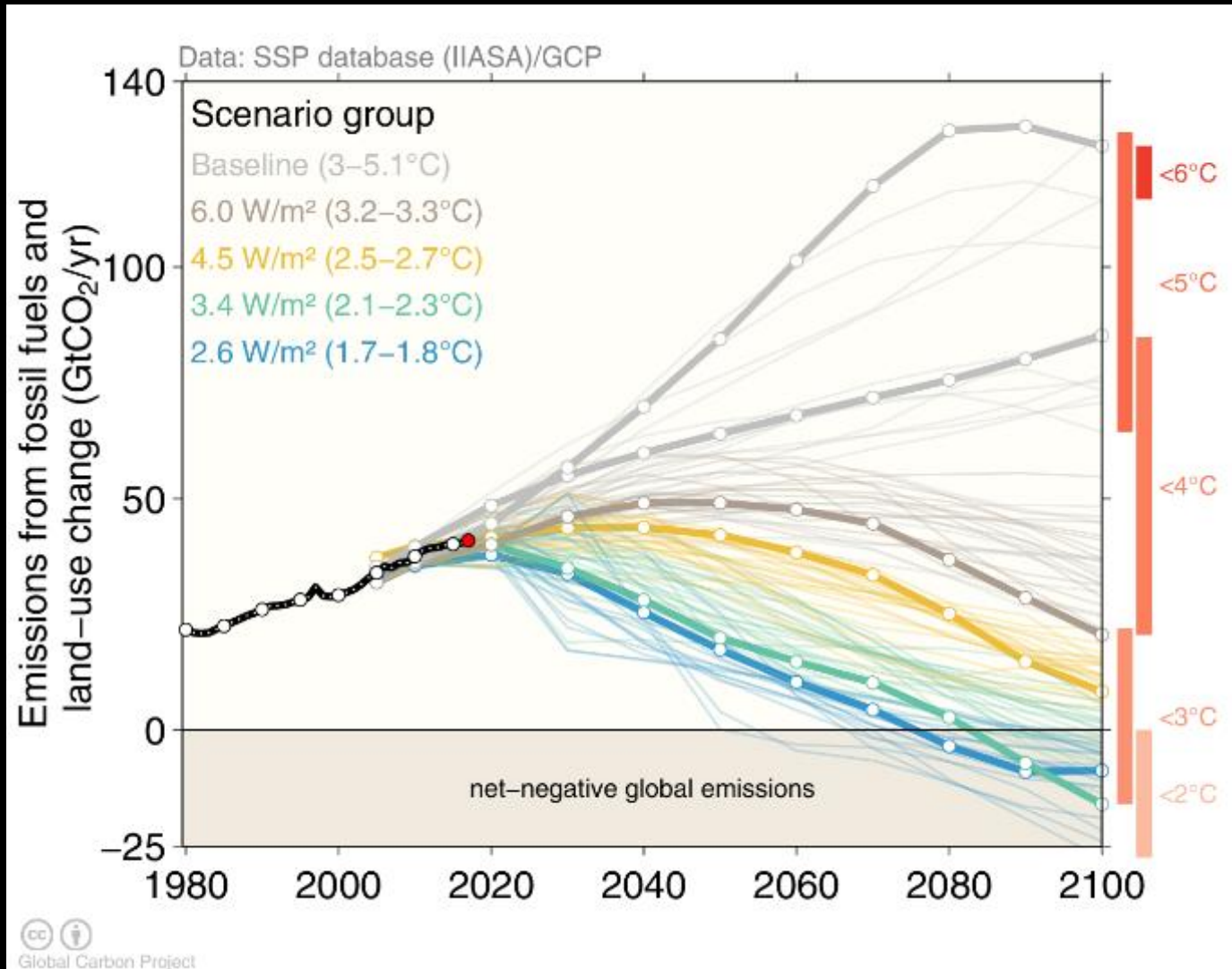
20+ years of model development and applications



Most working groups have winter/spring meetings.
Annual meeting in June.



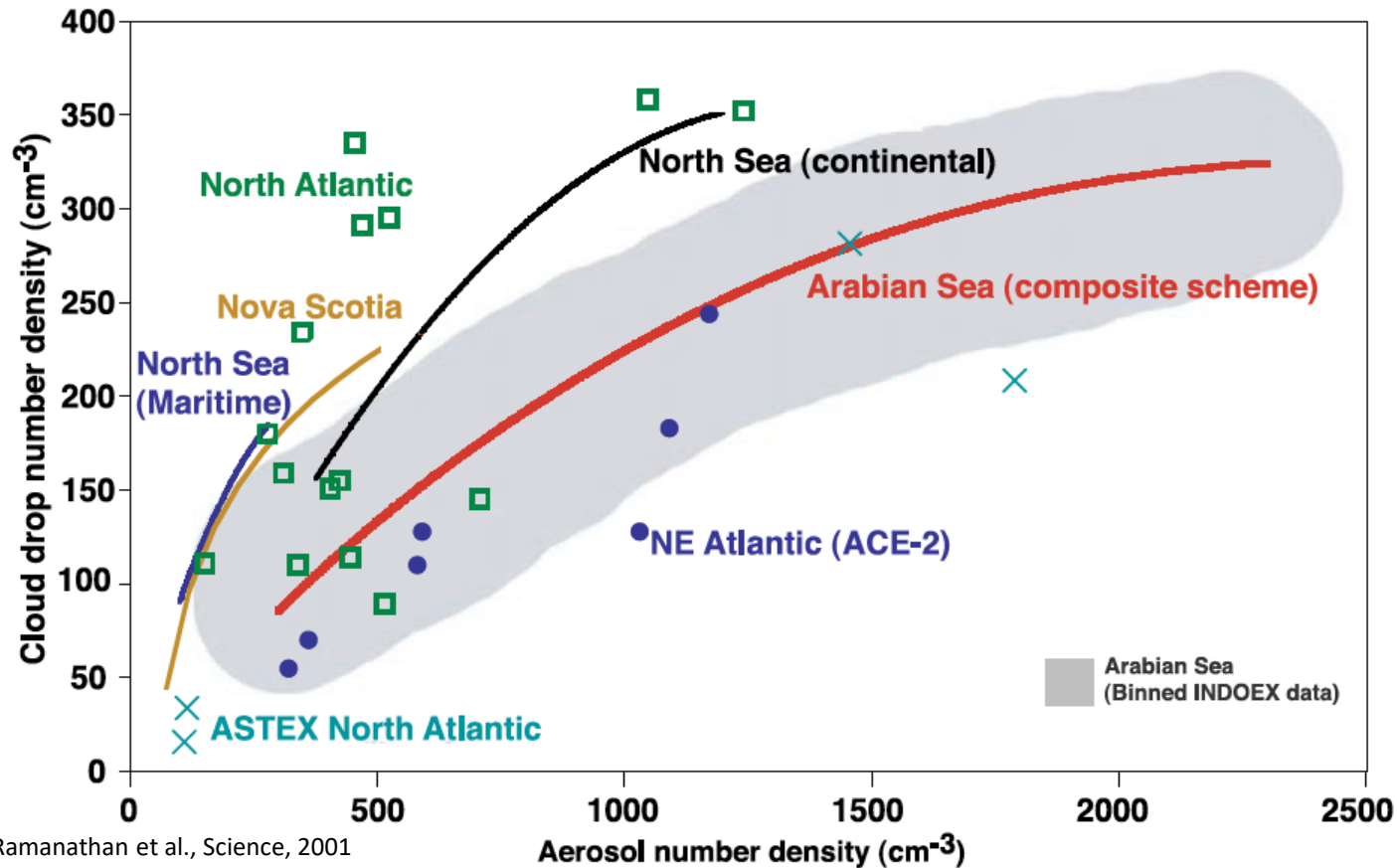
New generation of emissions scenarios



Five Shared Socioeconomic Pathways (SSPs) have been developed to explore challenges to adaptation and mitigation. Shared Policy Assumptions (SPAs) are used to achieve target forcing levels (W/m²). Marker Scenarios are indicated.
Source: [Riahi et al. 2016](#); [IIASA SSP Database](#); [Global Carbon Budget 2017](#)

THE formation of cloud has been generally ascribed to the rising of a mass of saturated air to a cooler stratum, where the cooling due to expansion and that from the surrounding air produces a supersaturation and visible cloud. Not long since, Mr. John Aitken of Scotland propounded the rather startling theory that cloud could *not* be formed without the intervention of solid particles of dust, smoke, or other substance. This view was based on laboratory experiments, in which dust-free air seemed to show no condensation upon rarefaction. It would seem as though this view can hardly be possible. If two molecules of vapor have been sufficiently cooled, why may they not coalesce into a double molecule of water? If we consider that each double molecule of water needs a solid particle for a nucleus, there will be needed enormous quantities of these particles in each cloud, and more, it would seem, than can possibly be present in the cloud-forming strata.

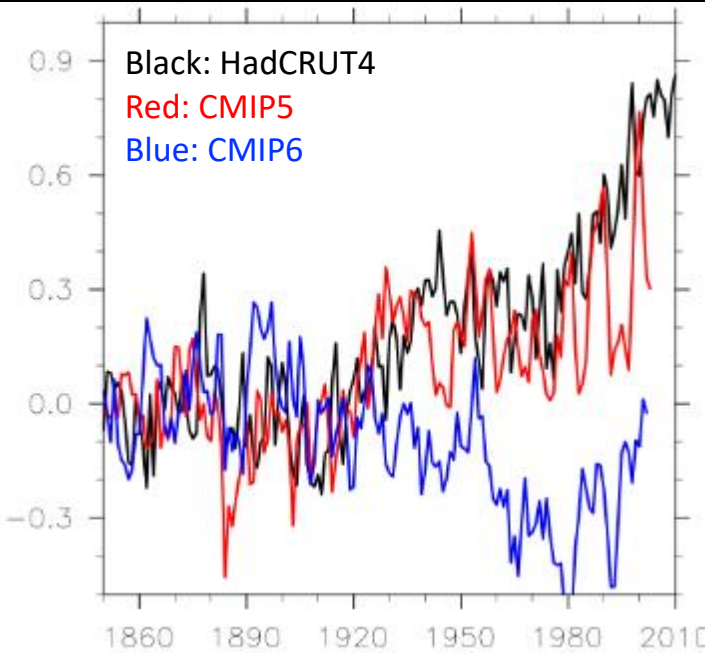
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experimer



Ramanathan et al., Science, 2001

molecule of water needs a solid
needed enormous quantities of
more, it would seem, than can
ning strata.

Global TS anomaly w.r.t 1850-1880

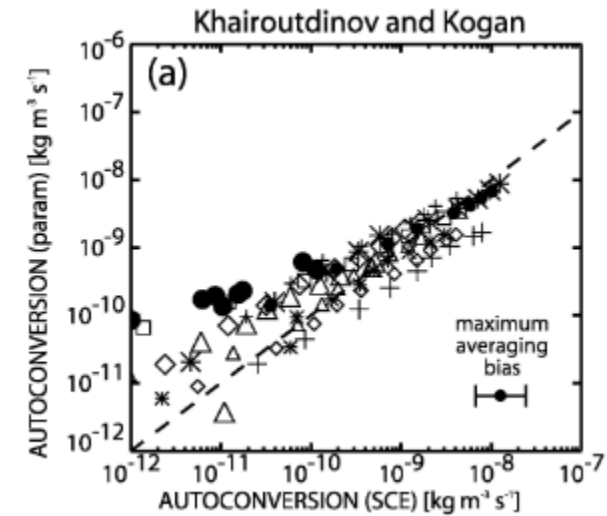
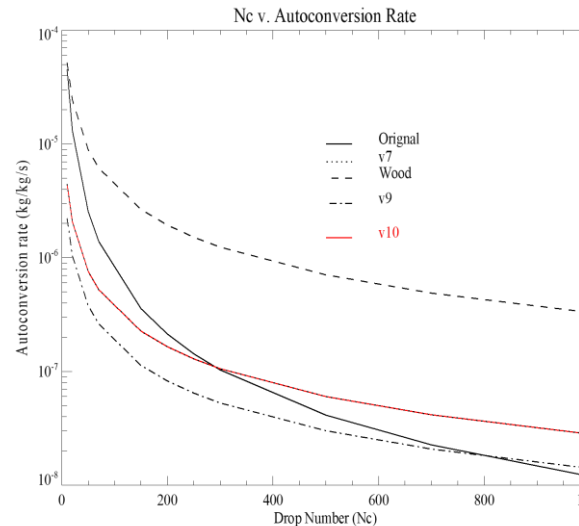


$$Au = kL^a N^b$$

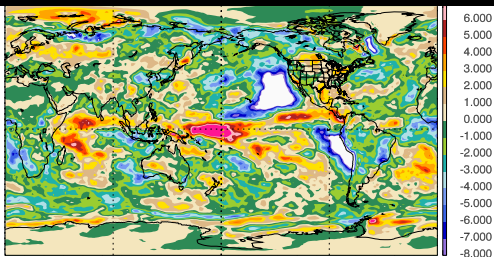
Au =autoconversion rate

L =cloud liquid (kg/kg)

N =droplet number (#/kg)



Wood, 2005



Difference in short-wave cloud forcing (SWCF)

Climate Predictions with CESM on Sub-Seasonal to Decadal Timescales

CESM – Decadal Prediction
Large Ensemble (40 members)

Summer Precipitation in the Sahel

Steve Yeager et al. (BAMS, 2018)

